Scaling complexity: novel hydraulic flume experiments on the interaction of sediments with nutrients and pollutants

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Institute of Hydraulic Engineering and River Research

BOKU University

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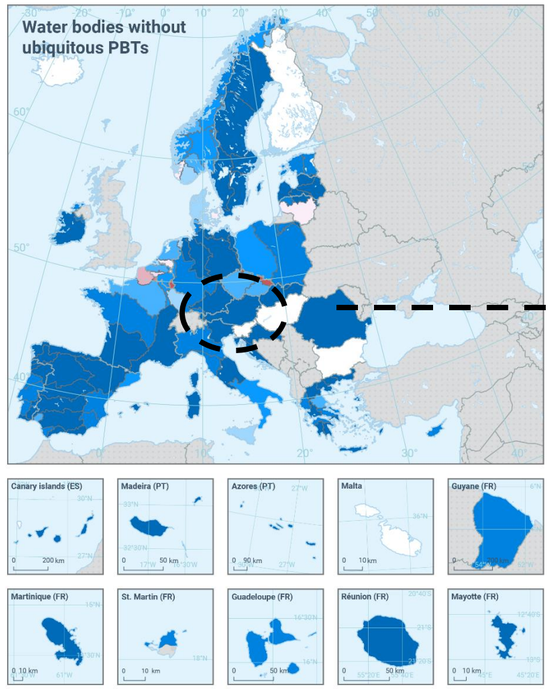
Scope

Water bodies failing to achieve good chemical status in 2021 (3rd RBMP)



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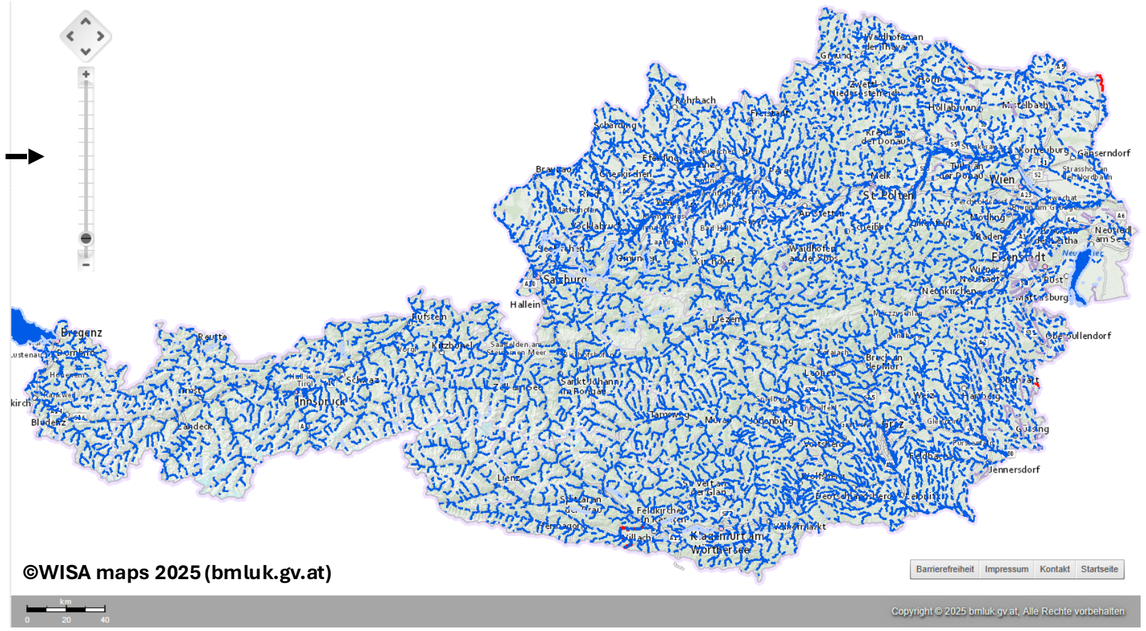
Current situation in Austria

Chemical status of surface waters without ubiquitous pollutants



Scope

Water bodies failing to achieve
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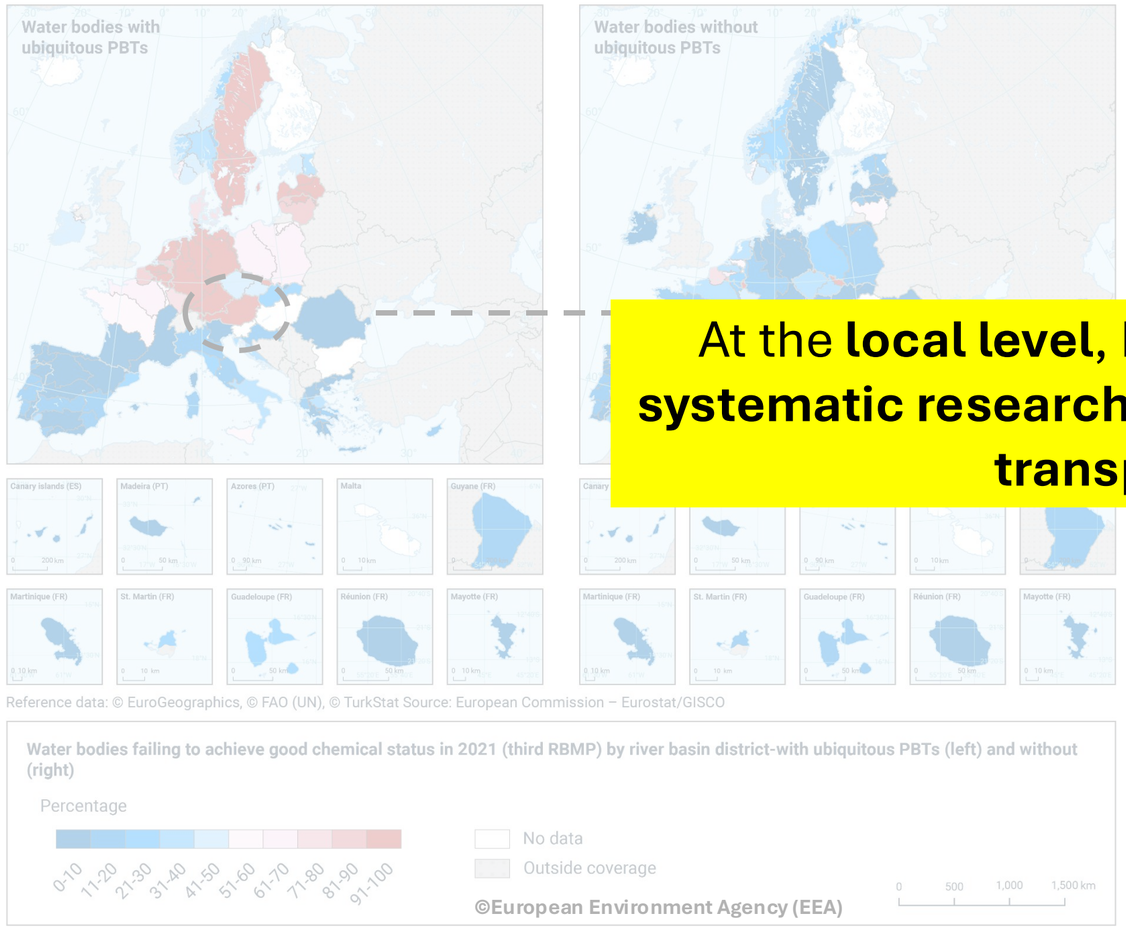
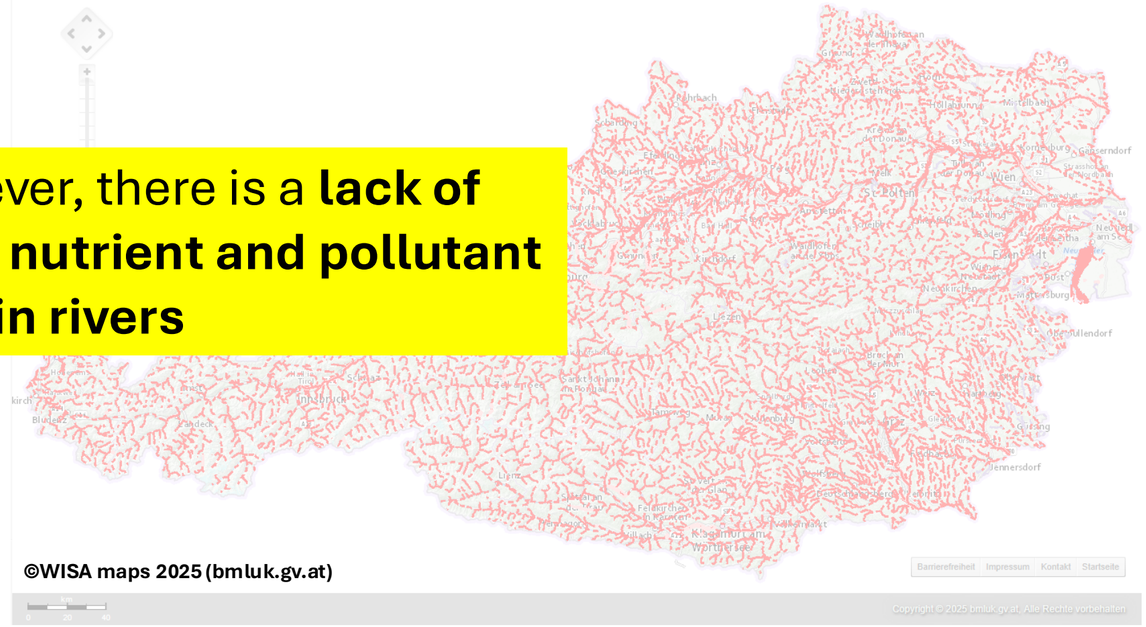


Current situation in Austria
Chemical status of surface waters
with ubiquitous pollutants (in particular Hg, PBDE)



At the **local level**, however, there is a **lack of systematic research into nutrient and pollutant transport in rivers**

Case study – River Maltsch (AT/CZ)

Contents lists available at ScienceDirect

Limnologica

journal homepage: www.elsevier.com/locate/limno

Determination of particle-bound nutrients and micropollutants concentrations and loads in small rivers – A novel sampling method

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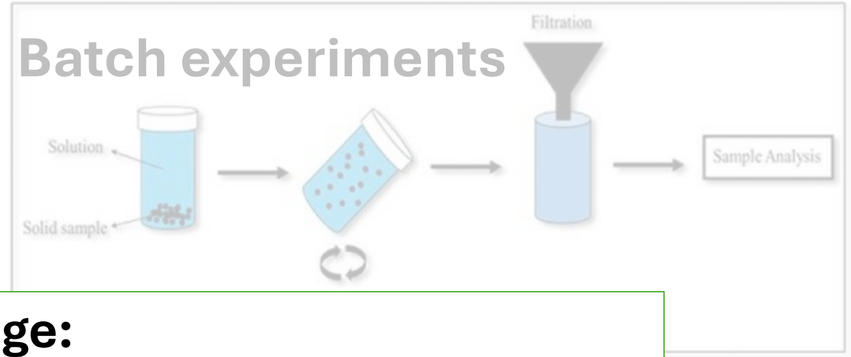
How can we apply these findings to other catchment areas and rivers?

Problem definition

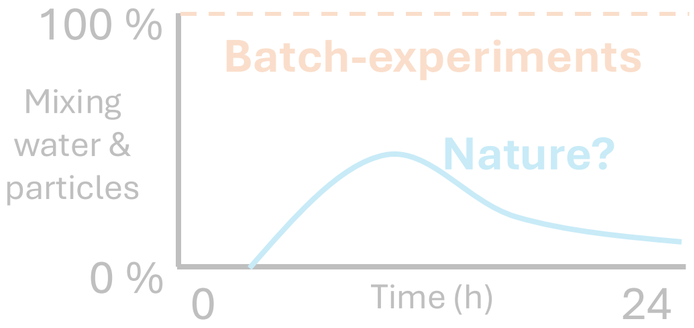
→How do the **main processes** (transport, deposition, remobilisation) influence the **distribution of nutrients and pollutants under natural conditions**?

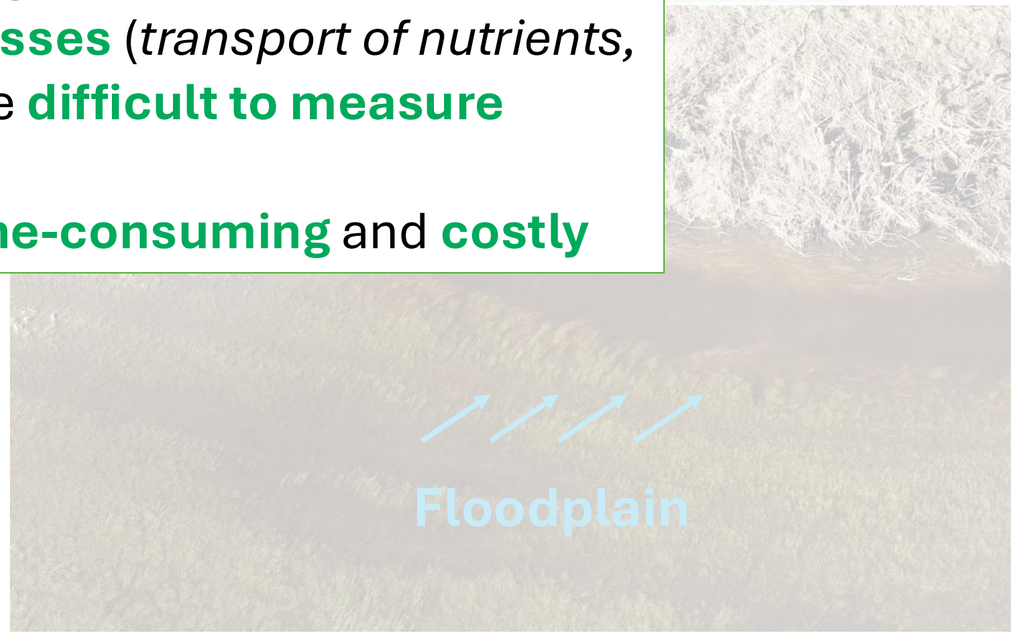


Key message:

In nature, there are **unsteady processes** (*transport of nutrients, pollutants, sediments*) that are **difficult to measure**

→ **Sampling and analysis** are **time-consuming** and **costly**



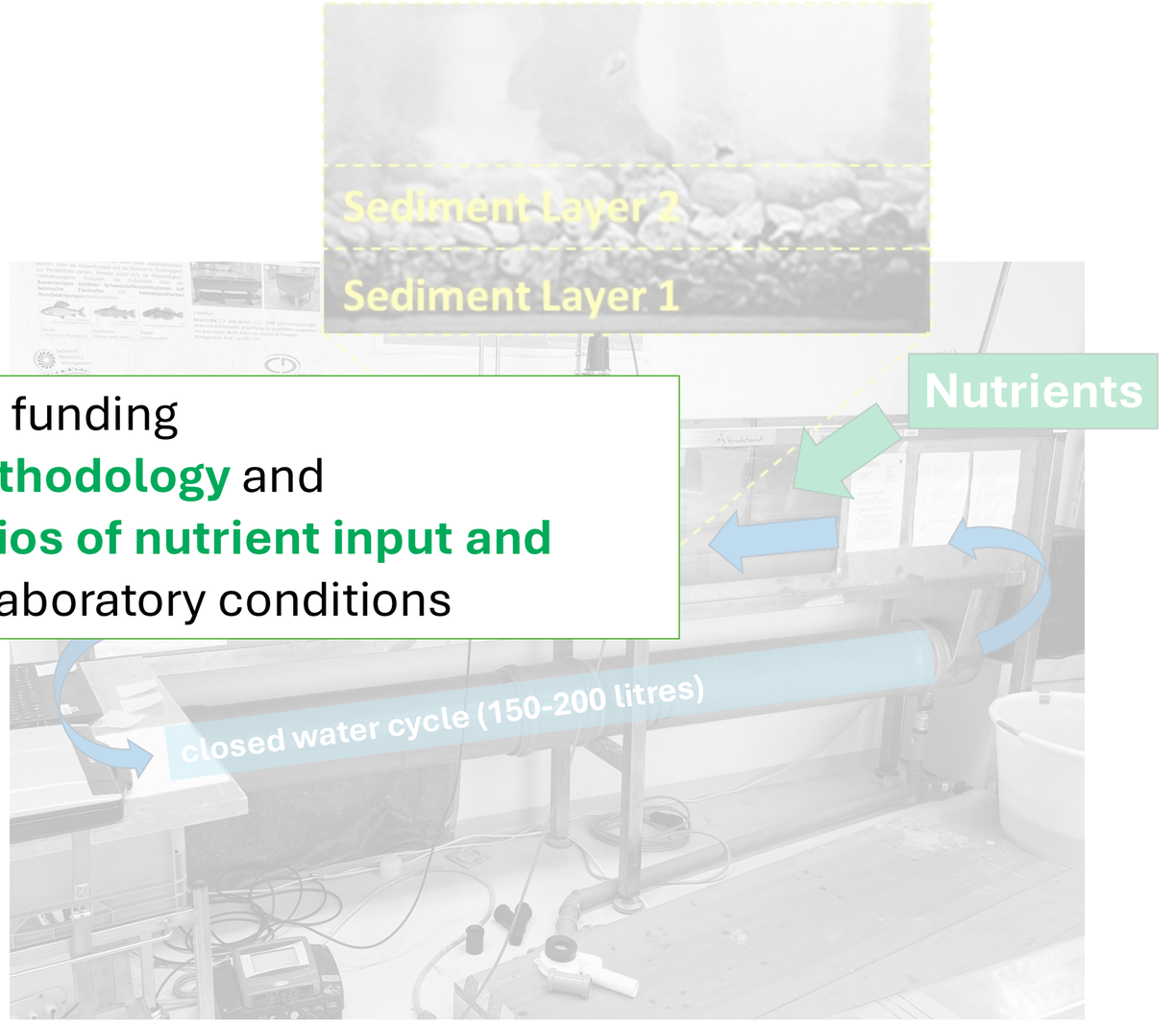


Project idea

Investigating **nutrient and pollutant transport in flume experiments** under controlled **morphological and physico-chemical conditions**

Sediment layer (i-iv)

We received funding
to **validate the methodology** and
investigate selected scenarios of nutrient input and sediment layers under laboratory conditions



Nutrient influx scenarios:
(a) liquid, (b) manure
(c) spiked sediment, (d) soil

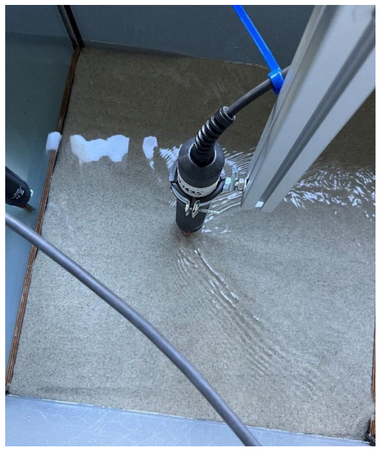
Experimental setup and methods (1)

- **Flume** (400 x 60 x 35 cm), circulating water circuit (150–200 L)
- **Sediment cores**: 1 or 2 layer quartz sand

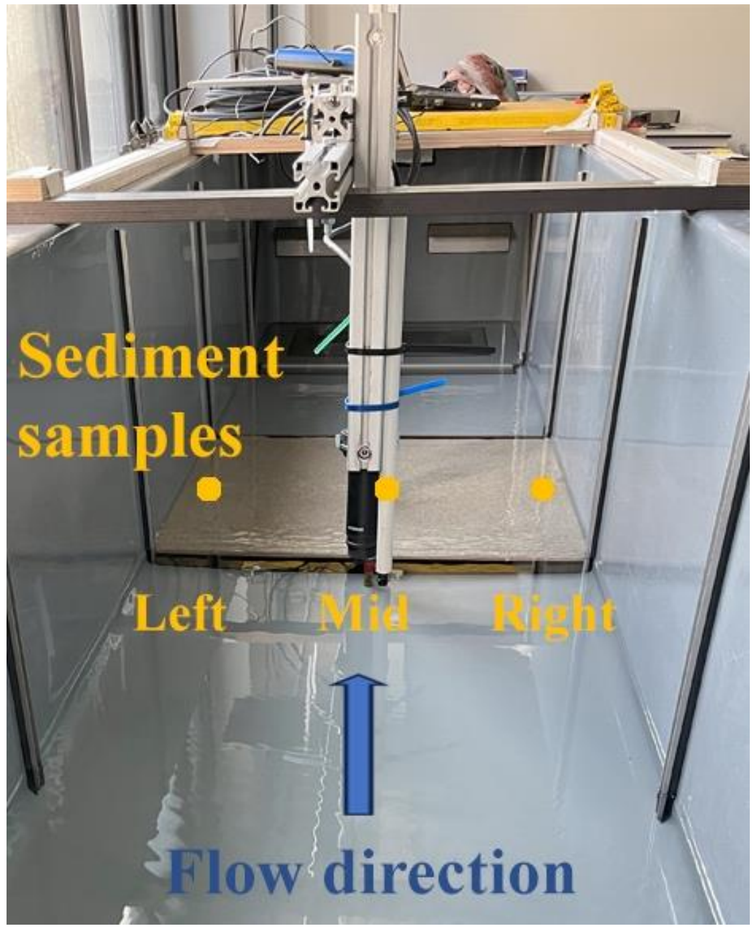
→ *Related to previous research work in the Bohemian Massif (AT, CZ)*

- **Selected nutrients**
  - **NPK liquid fertiliser**
  - Peat-free potting soil
  - Animal manure
- **Entry points**
  - **Into the water**
  - **Below the sediment core**

d = 0,4 – 0,8 mm



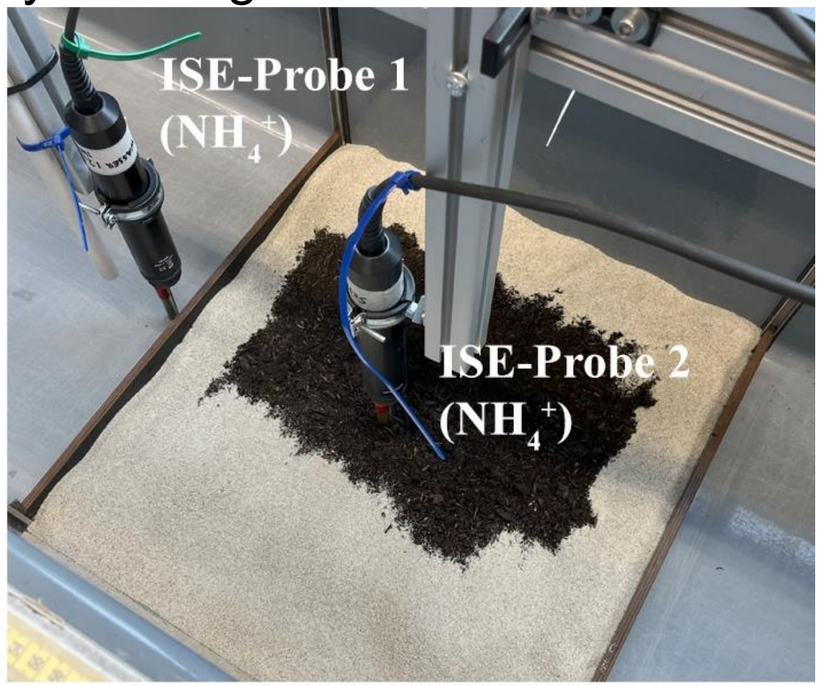
d = 4 – 8 mm

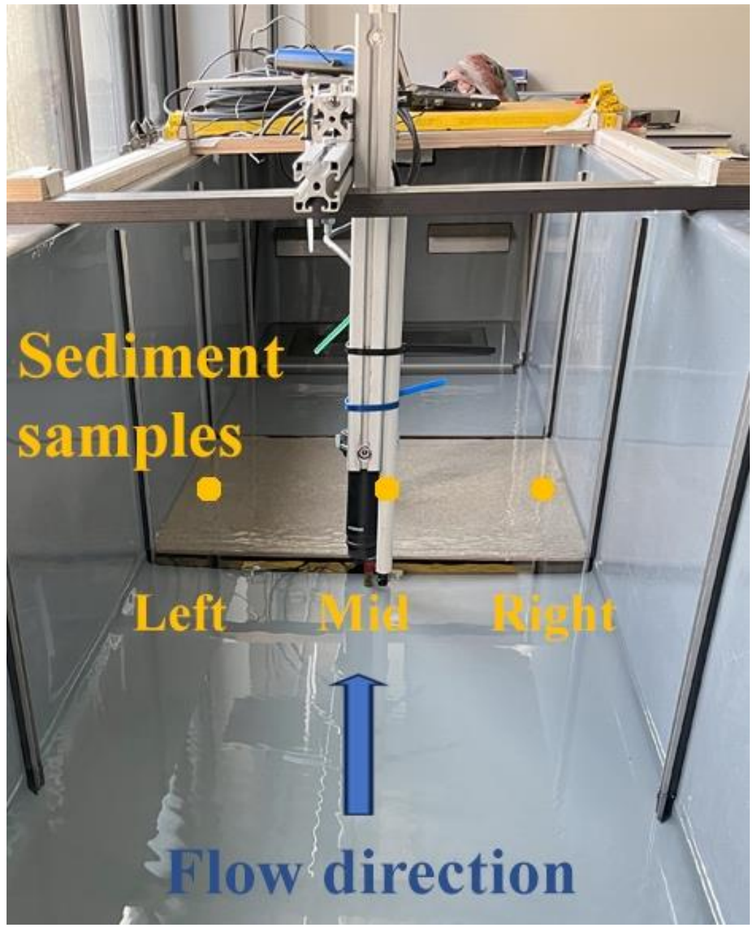


Experimental setup and methods (2)

- Each experiment lasted **24 hours**
- **One water sample** and **three sediment samples**
- Trace element and nutrient analysis using ICP-OES

- **Continuous recording of ppm ammonium concentrations** *(Hanna Instruments HI9829; ISE HI7609829-10)*
- In addition, standard physical-chemical parameters

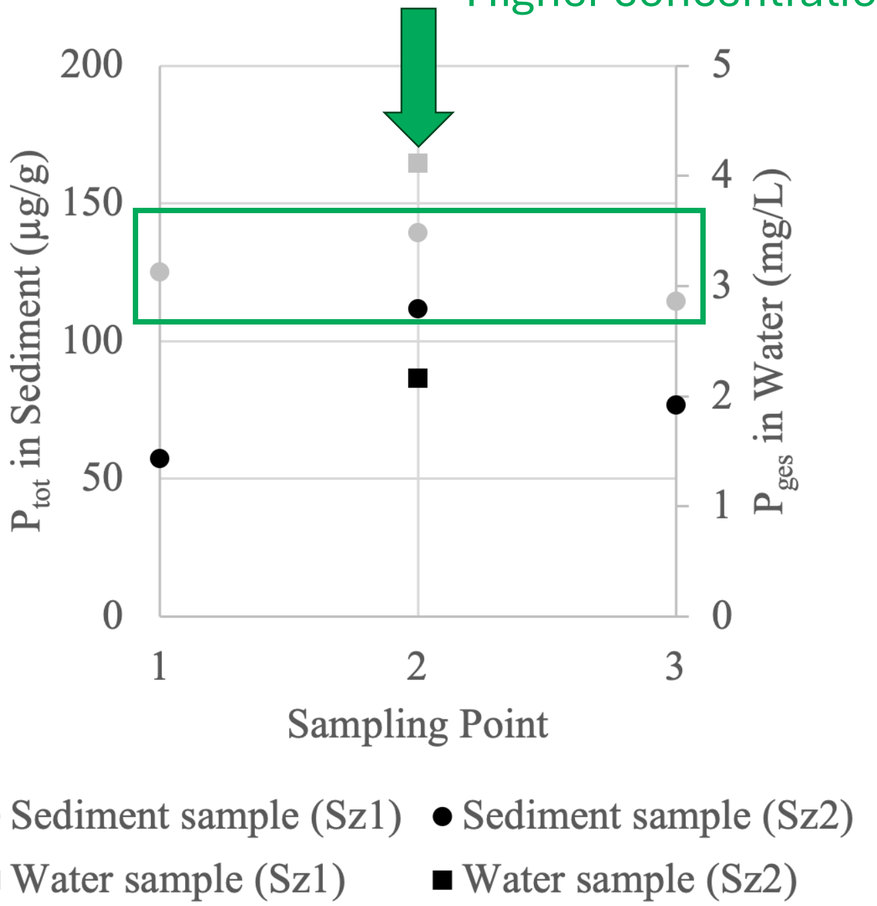


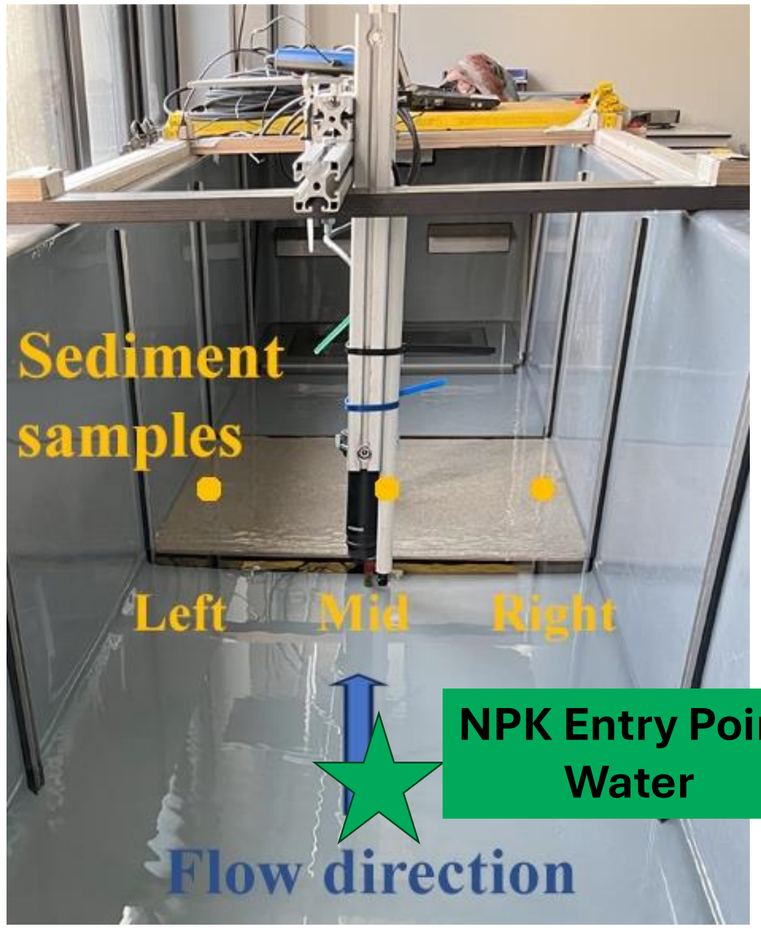


Results (1) – Spatial distribution of nutrients

Concentration differences in the cross-section

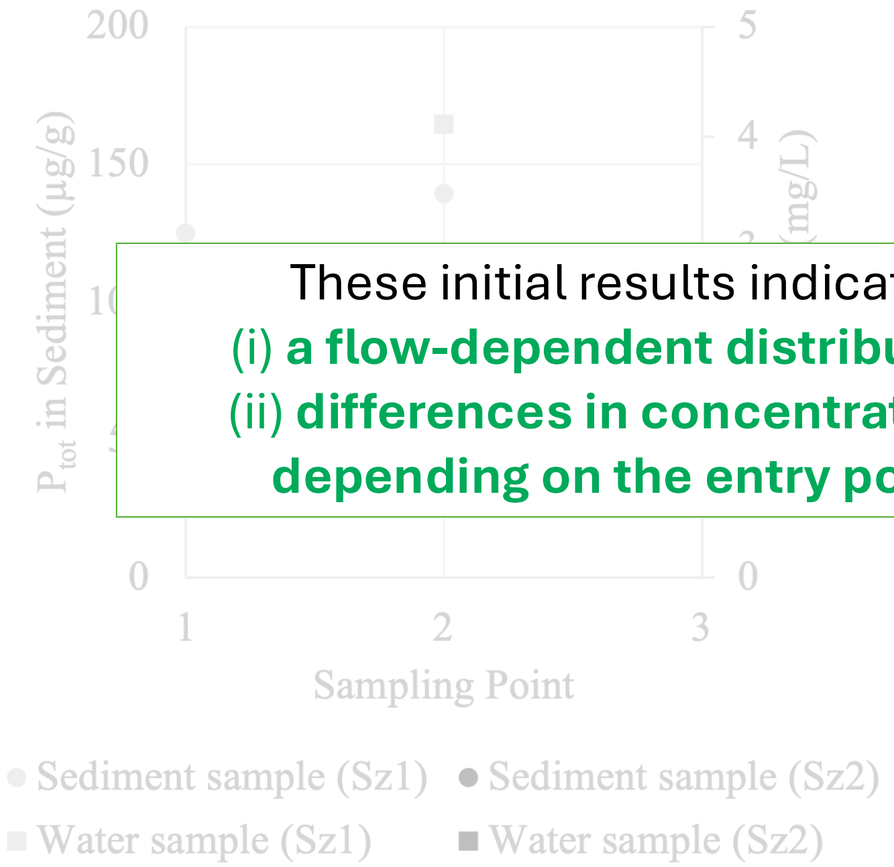
Higher concentration of P_{tot} in water



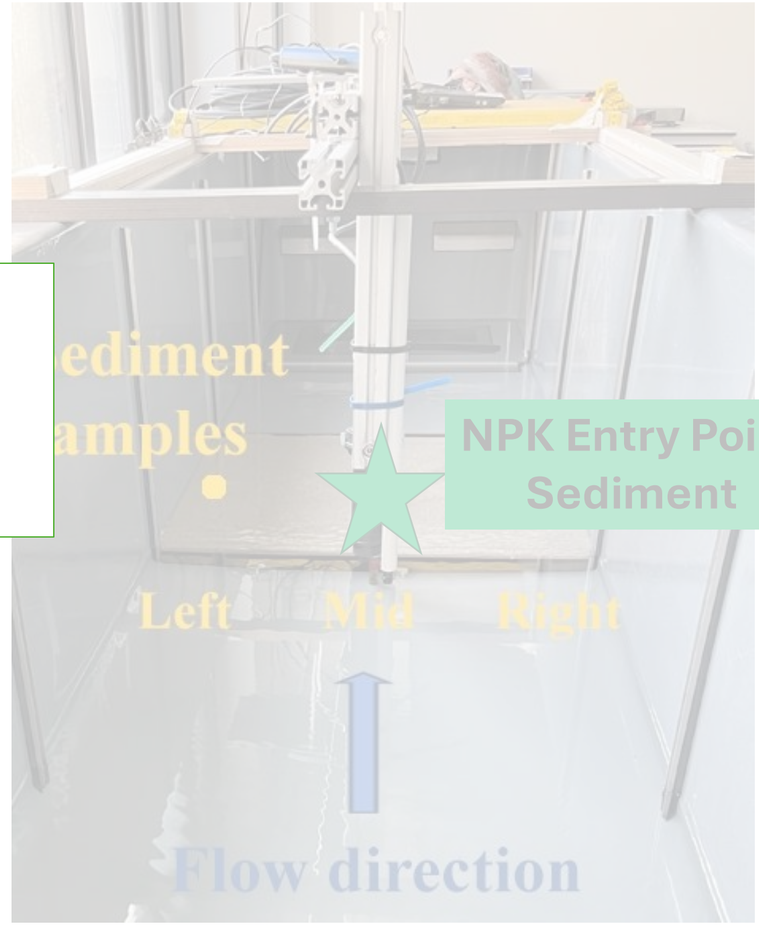


Results (2) – Spatial distribution of nutrients

Concentration differences in the cross-section



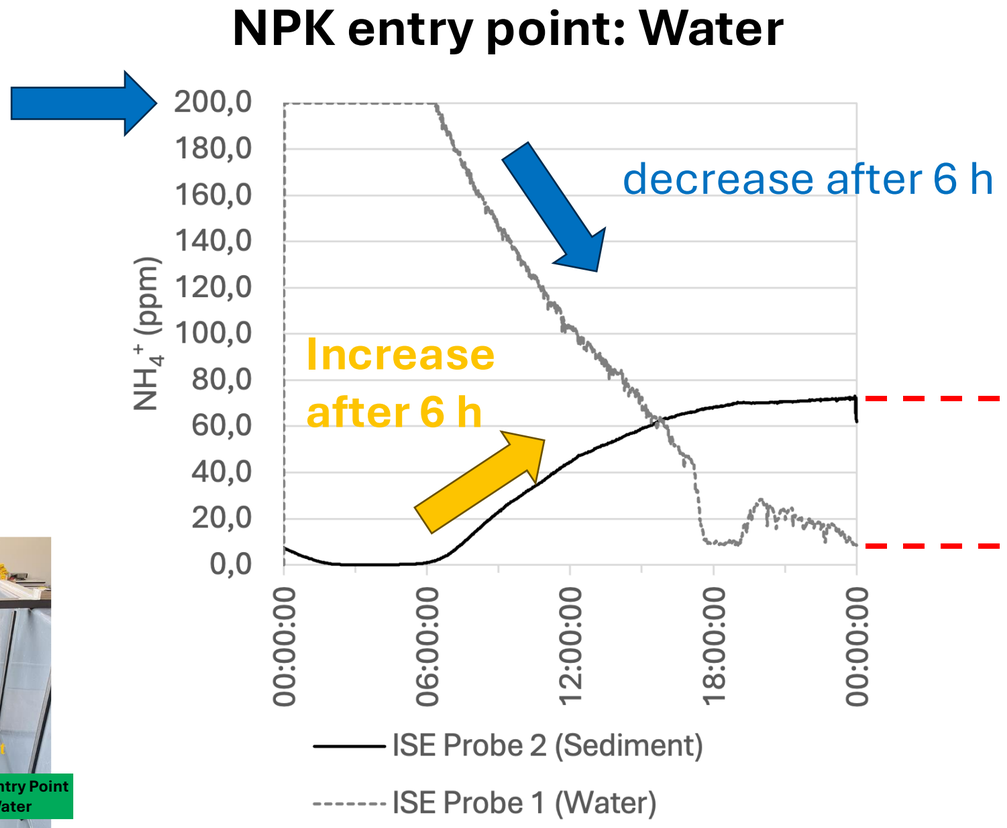
These initial results indicate:
(i) **a flow-dependent distribution**
(ii) **differences in concentrations depending on the entry point**

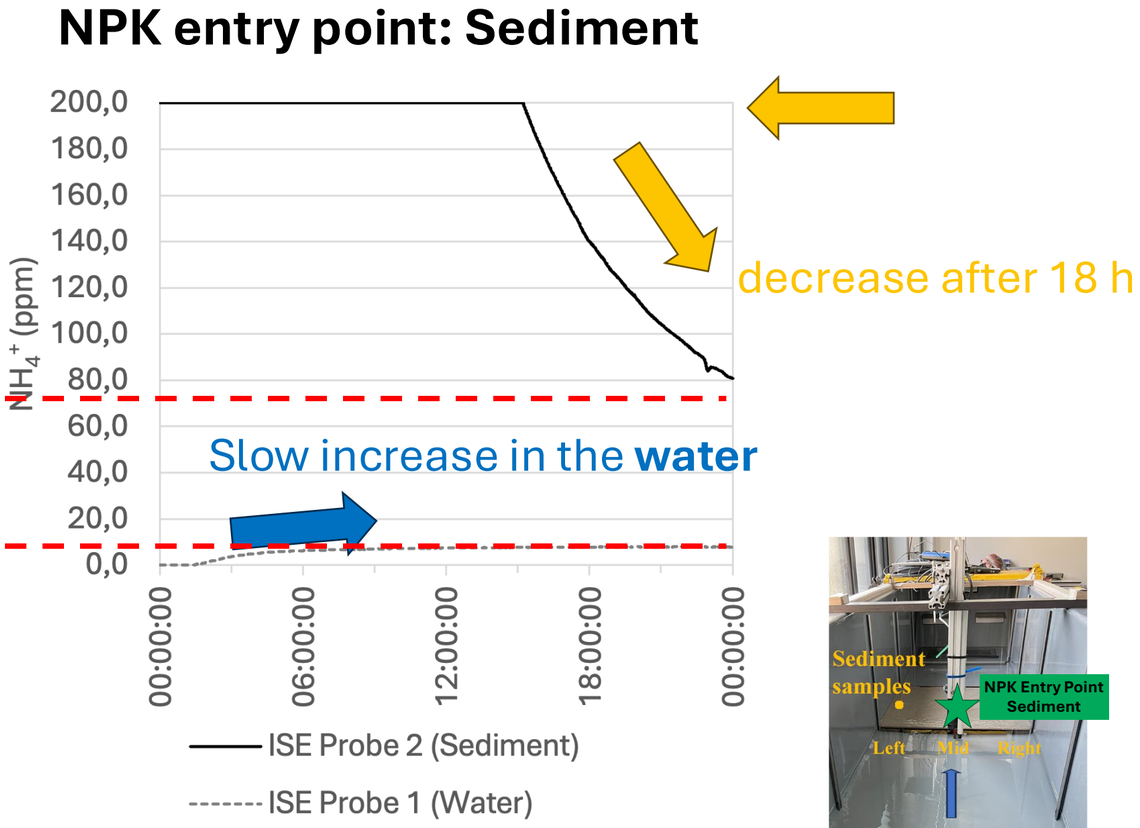


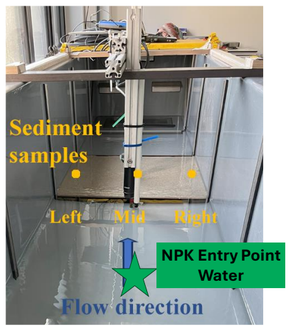
Results – Temporal distribution of nutrients

NH_4^+ peak in the **water**

NH_4^+ peak in the **sediment**





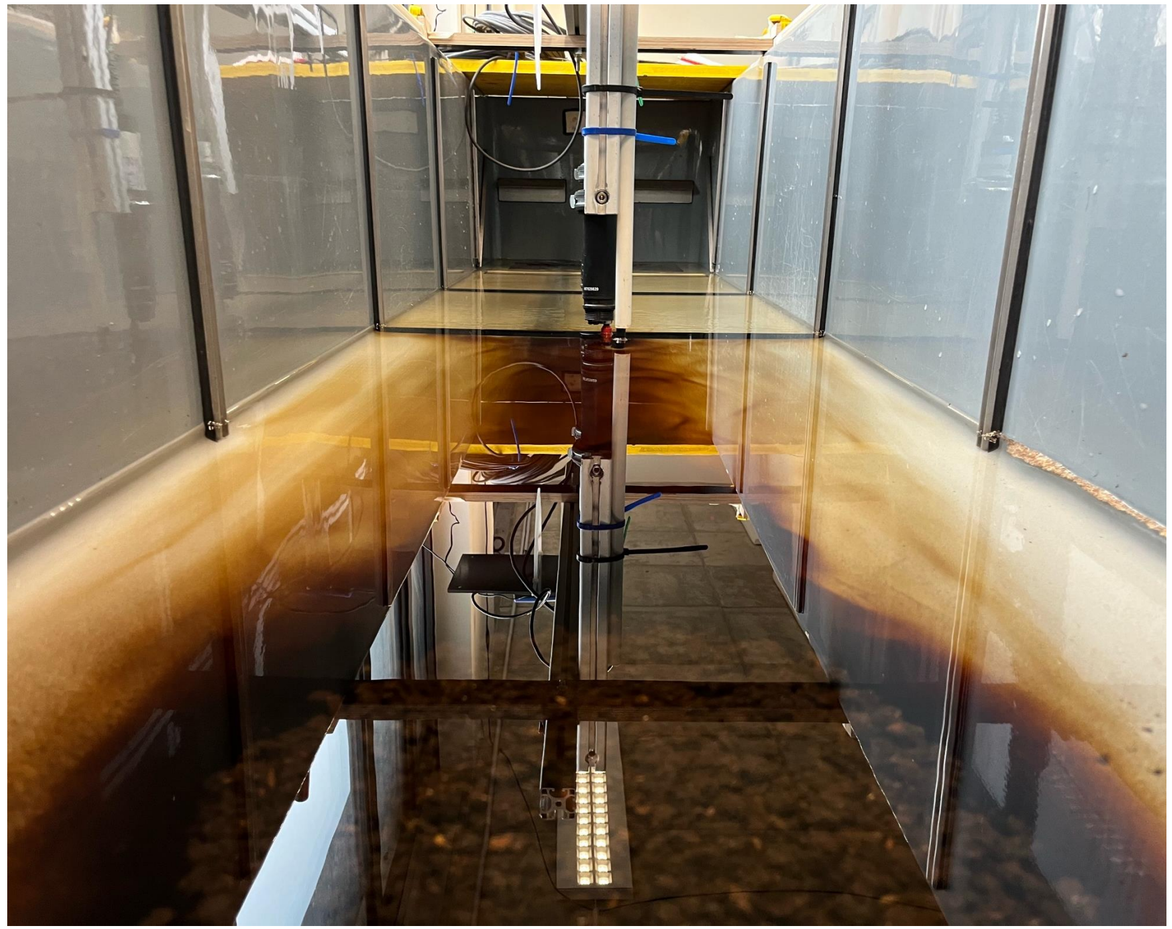


Summary of findings from this project

- The initial results indicate a **flow-dependent distribution**
- The **entry point** shows clear **differences in nutrient distribution**
- The **nutrient medium** had an **influence on the total concentrations** in the sediment/water
- The duration of the experiment is likely to have an impact

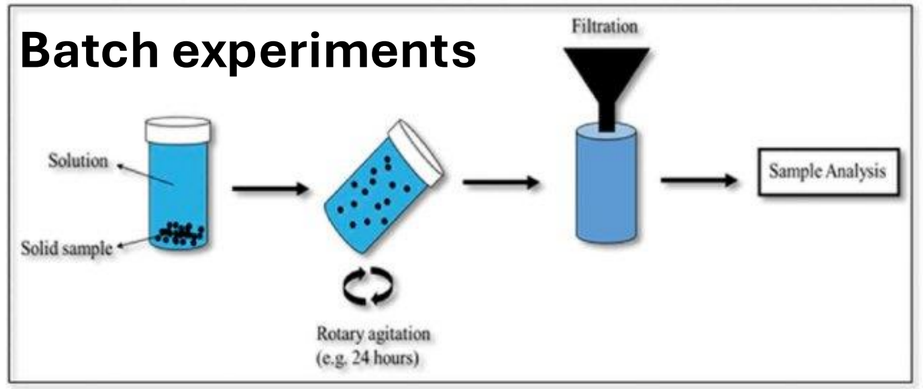
→unsteady processes in a (natural) river!

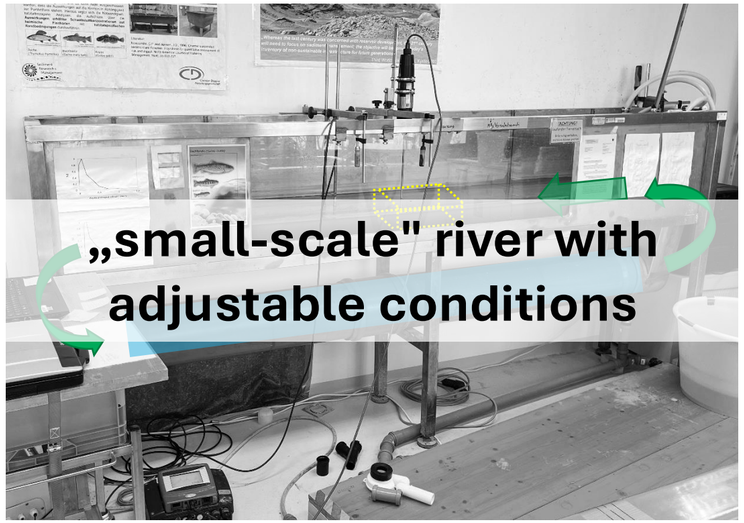
- Ion selective probes (ISE) should only be used as a supplement. A comparison with other manufacturers would be very interesting



Scaling complexity

Linking knowledge on nutrient and pollutant interactions between water and sediment





... and enhance it with laboratory experiments, in particular to address bioregion-specific issues

Implications for sediment research and management

- **Natural rivers are characterised by unsteady processes** (discharge, sediment transport)
- The (natural) variability of the river causes the determination of pollutants to be very complex
- The degree of **contamination of sediments with pollutants may also depend on the river morphology** → Economic aspects of flood protection and hydropower plants
- **Challenges** even with well-researched **particle-bound nutrients and pollutants**
  → a large number of samples is required
- **In addition** to the often cited influence **of grain size on nutrient and trace element concentrations**, the **hydraulic conditions should also be taken into account**
- **Bioregion-specific impacts** on sediment-water nutrient/pollutant interactions?

→ there is an **urgent need for research into the behaviour (mobility, fate) of ubiquitous substances**, as these are increasingly sampled and discussed in water rights negotiations

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Acknowledgements

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FWF Österreichischer Wissenschaftsfonds

ÖAW ÖSTERREICHISCHE AKADEMIE DER WISSENSCHAFTEN

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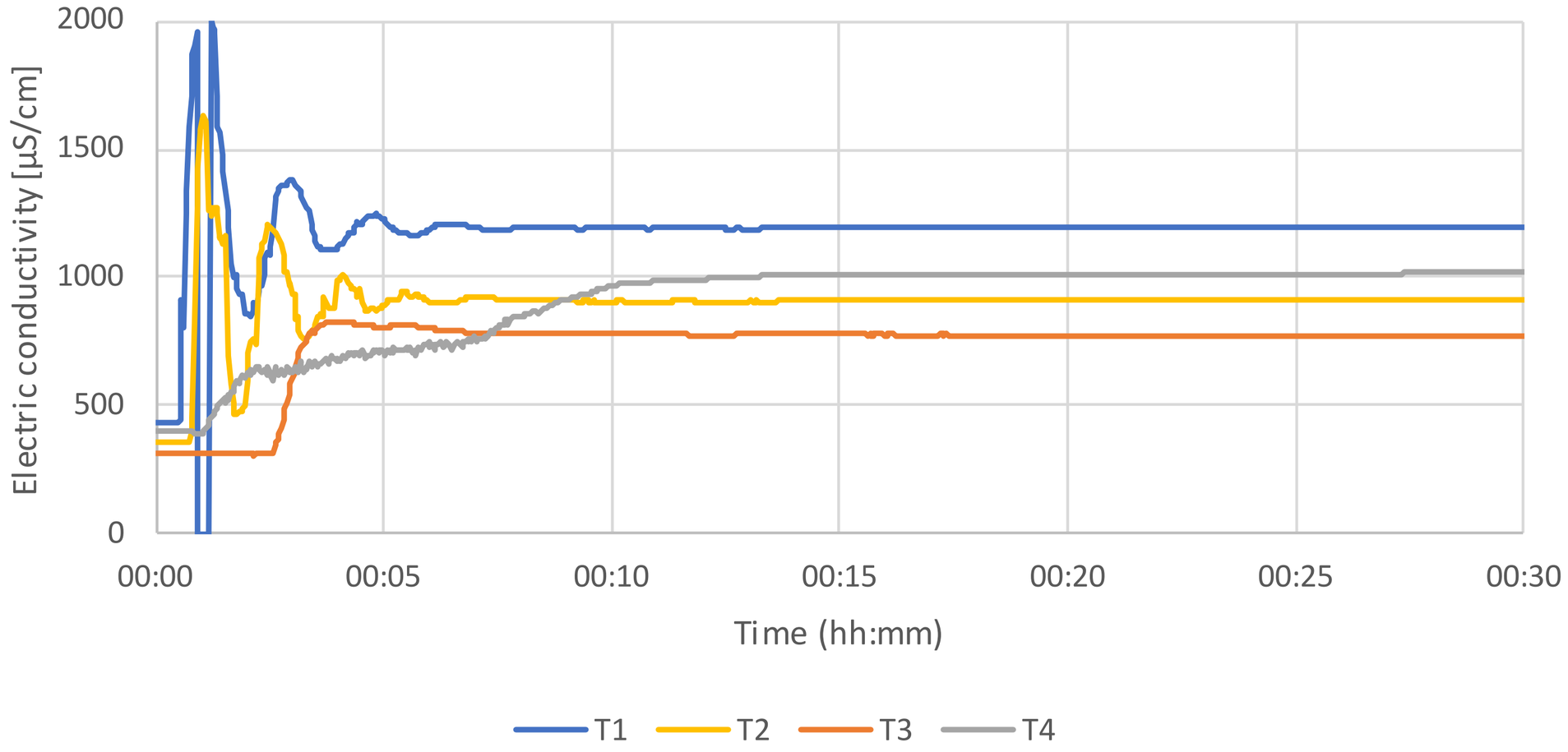


Figure 1: Preliminary investigations with conservative tracer (NaCl): Time course of the electrical conductivity as a function of the scenario (with and without sediment, addition to the aqueous phase or below the sediment core).

Preliminary experiments with conservative tracers

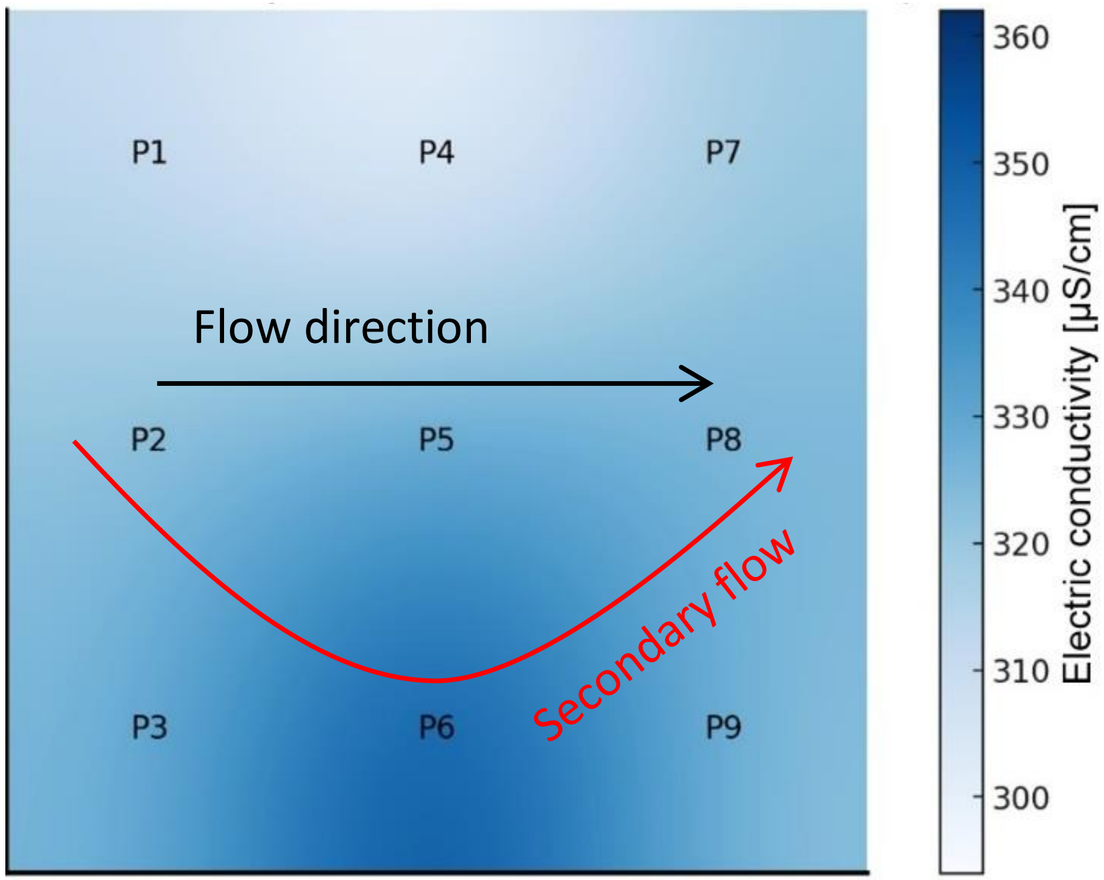
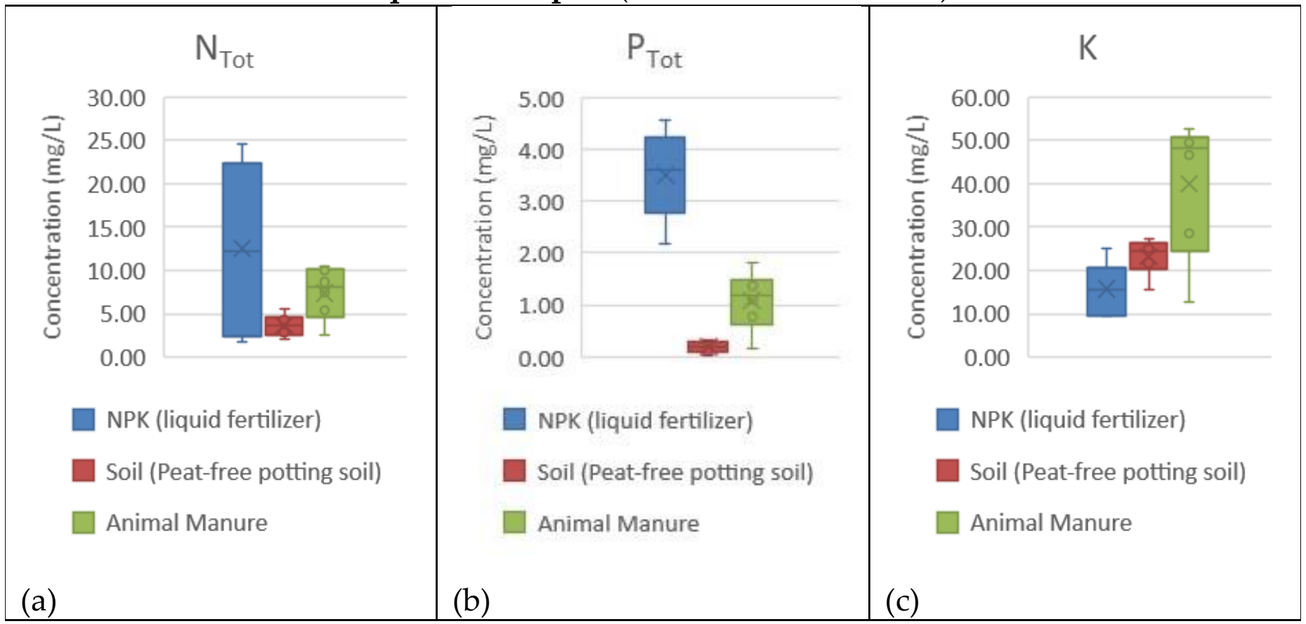


Figure 1: Preliminary investigations with conservative tracer (NaCl): Electrical conductivity in sediment core after 24 hours of exposure.

Aqueous samples (after 24h reaction time)



Sediment samples (after 24h reaction time)

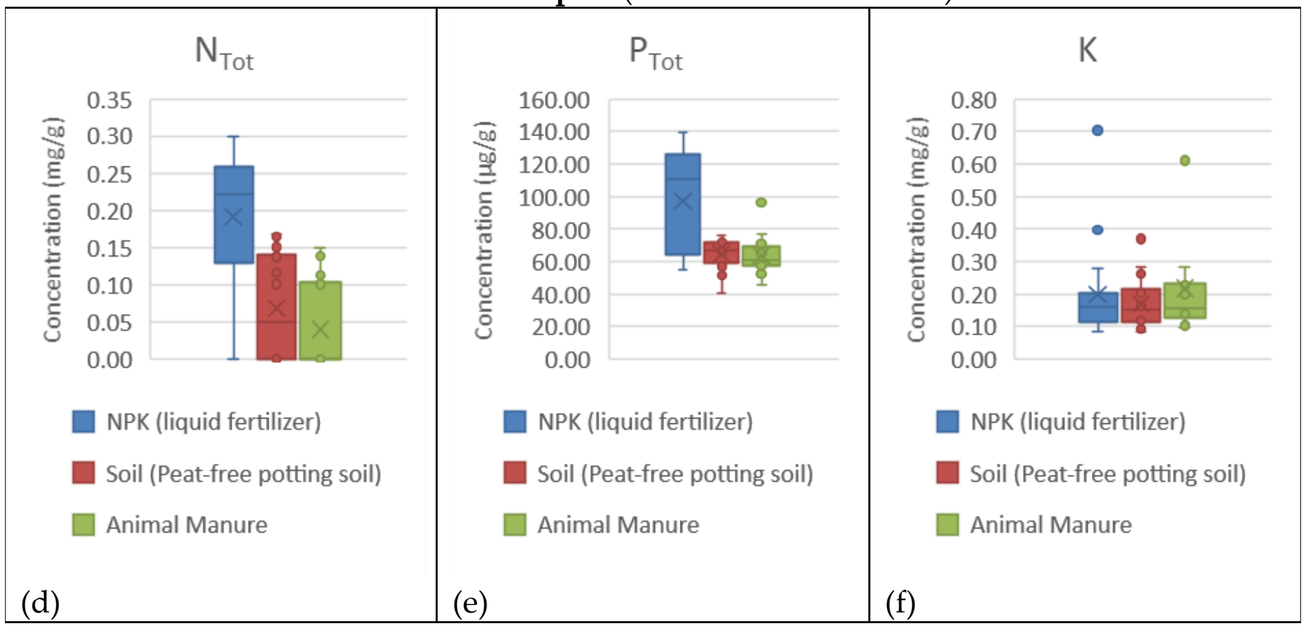
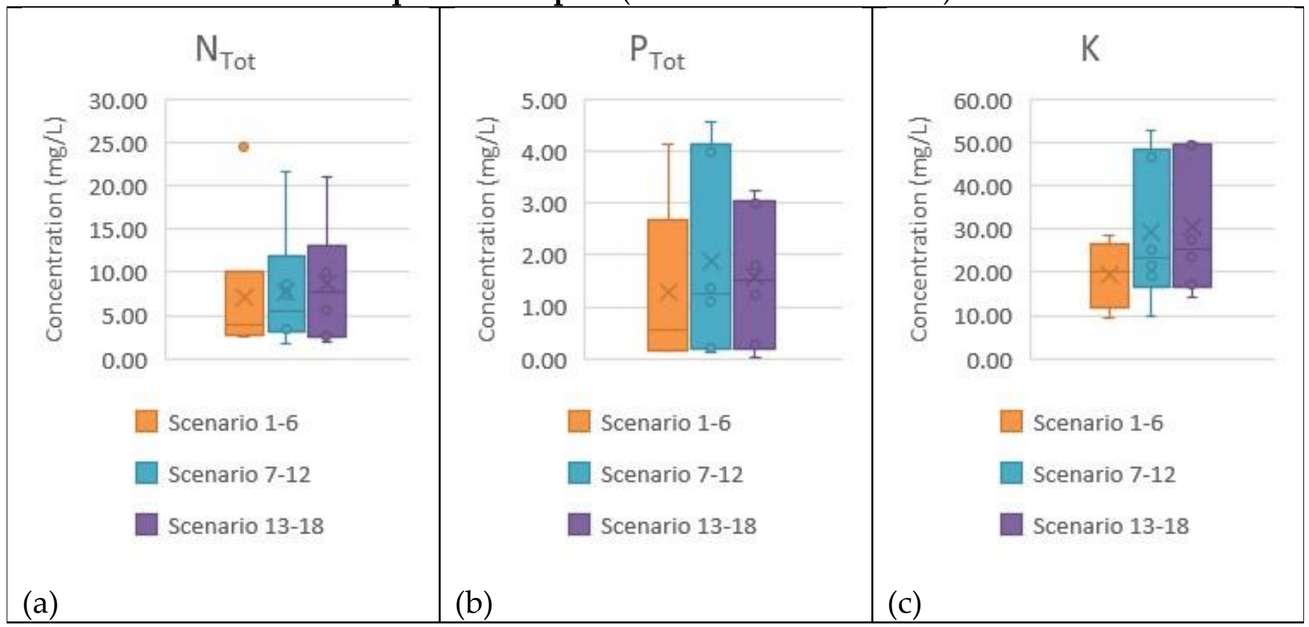


Figure 1: Presentation of nutrient concentrations after 24 hours of reaction time in the hydraulic flume experiment, depending on the nutrient medium (blue: NPK liquid fertilizer, red: peat-free potting soil, green: animal manure). (a)-(c) Aqueous samples; (d)-(f) Sediment samples.

Aqueous samples (after 24h reaction time)



Sediment samples (after 24h reaction time)

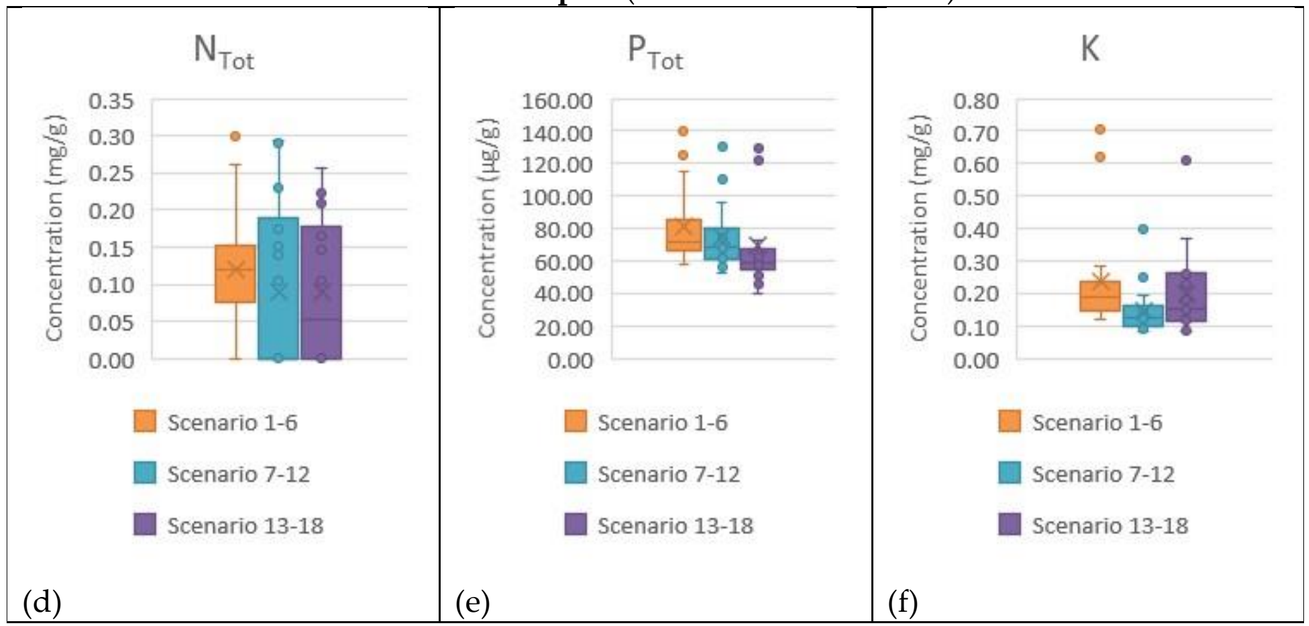


Figure 1: Presentation of nutrient concentrations after 24 hours of reaction time in the hydraulic flume experiment, depending on sediment scenarios: Scenario 1-6 (orange); Scenario 7-12 (blue); Scenario 13-18 (purple). (a)-(c) Aqueous samples; (d)-(f) Sediment samples.

Scenario 1-6 (1 Layer):
Sediment core (d=0,4-0,8 mm)

Scenario 7-12 (2 Layer):
surface layer: d=0,4-0,8 mm
subsurface layer: d=4-8 mm

Scenario 13-18 (2 Layer):
surface layer: d=4-8 mm
subsurface layer: d=0,4-0,8 mm

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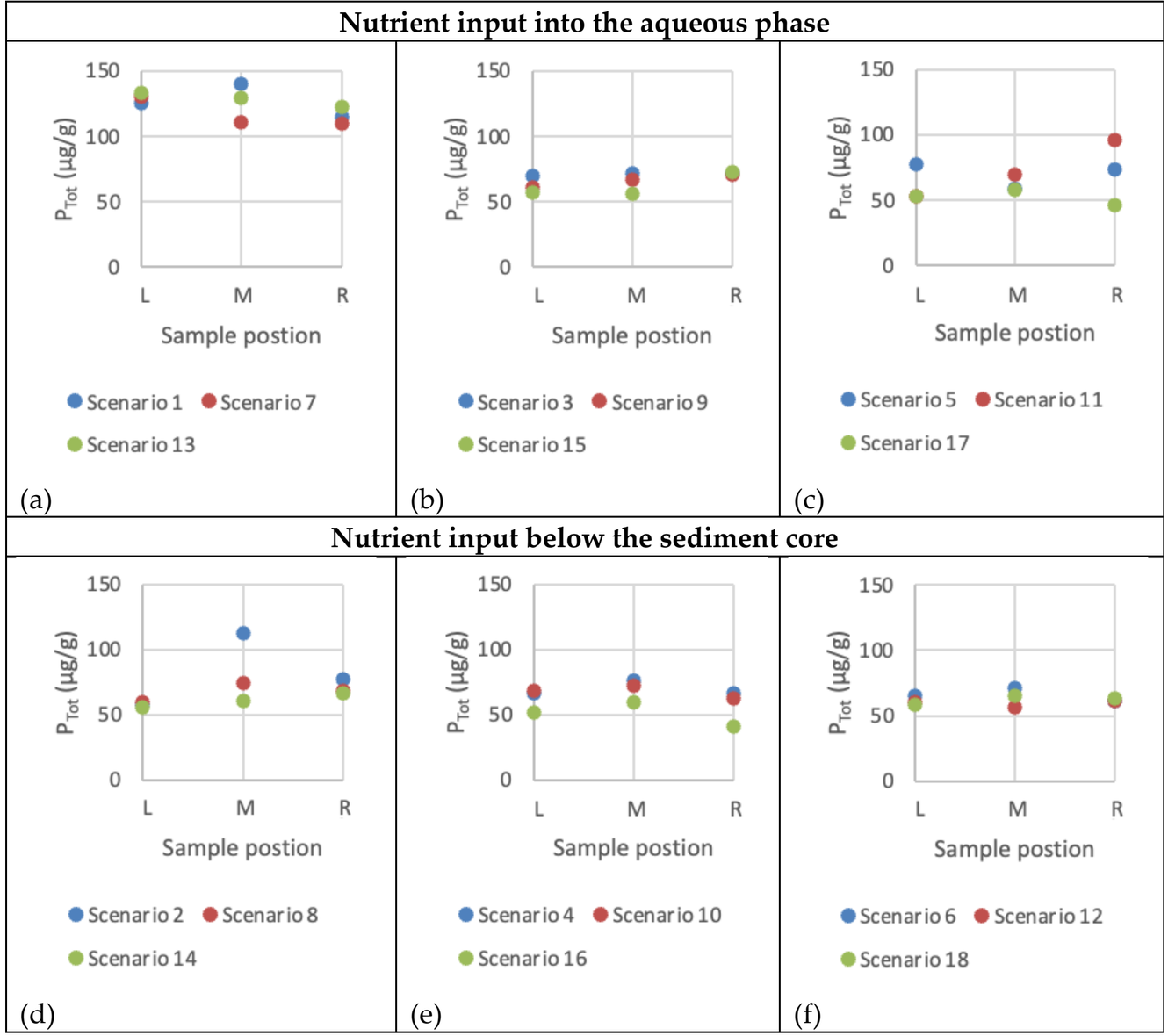

Figure 1: Presentation of nutrient concentrations in the sediment samples left (L), mid (M) and right (R) after 24 hours of reaction time in the hydraulic flume experiment: (a) NPK liquid fertilizer added to the aqueous phase, variation in sediment stratification; (b) peat-free potting soil added to the aqueous phase, variation in sediment stratification; (c) animal manure added to the aqueous phase, variation in sediment stratification. (d) NPK liquid fertilizer added below the sediment core, variation in sediment stratification; (e) peat-free potting soil added below the sediment core, variation in sediment stratification; (f) animal manure added below the sediment core, variation in sediment stratification.

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Sediment core (d=0,4-0,8 mm)

Scenario 7-12 (2 Layer):
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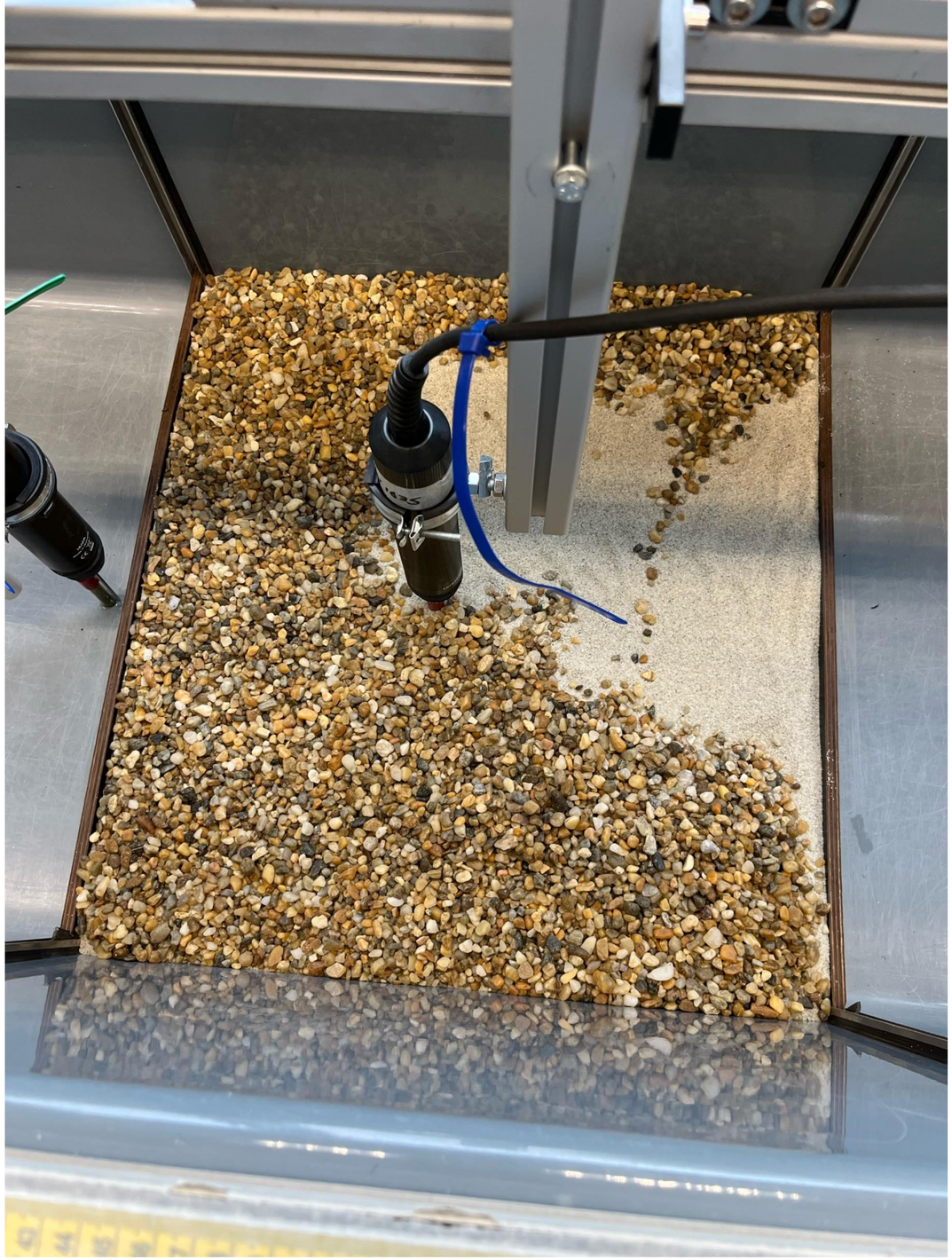

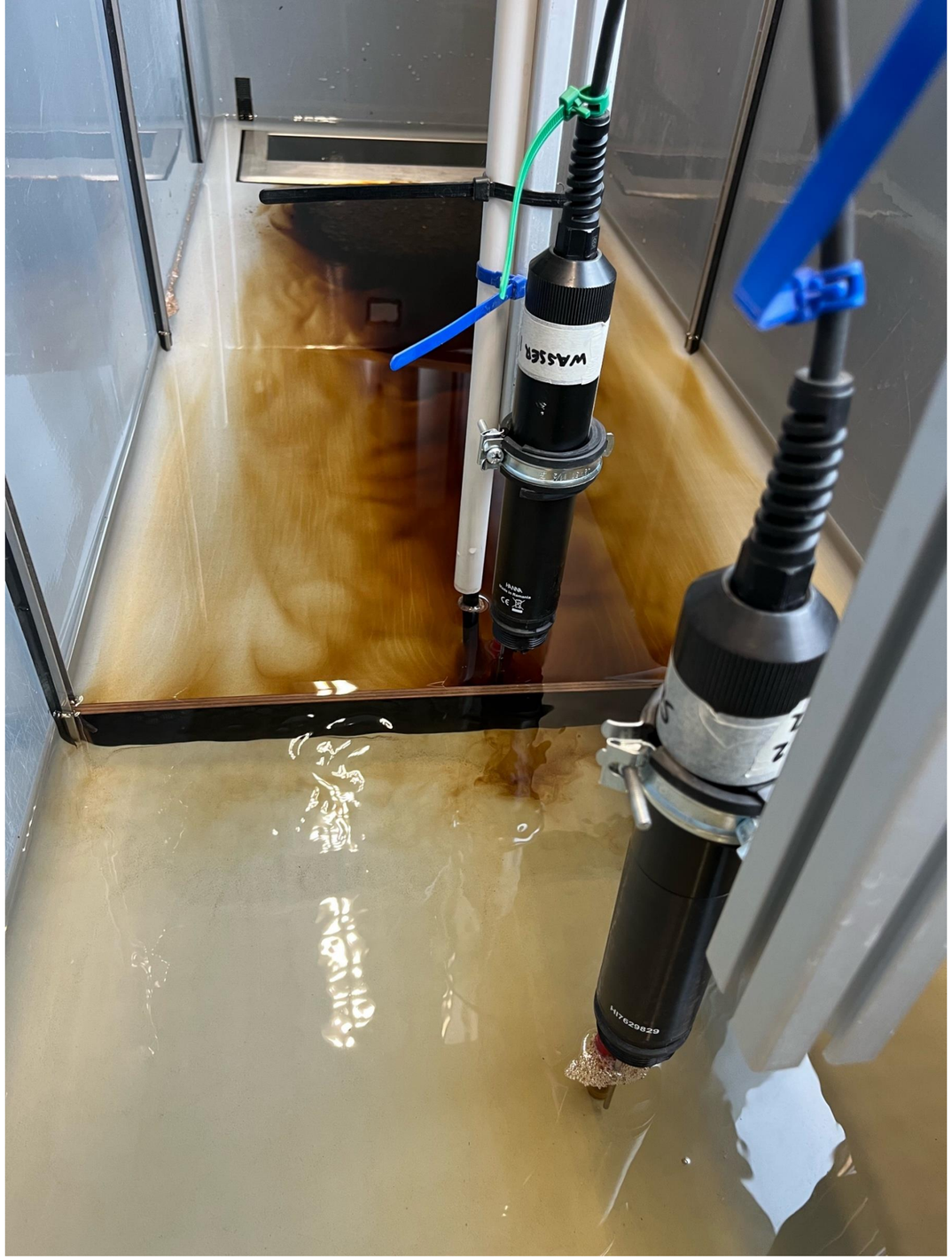

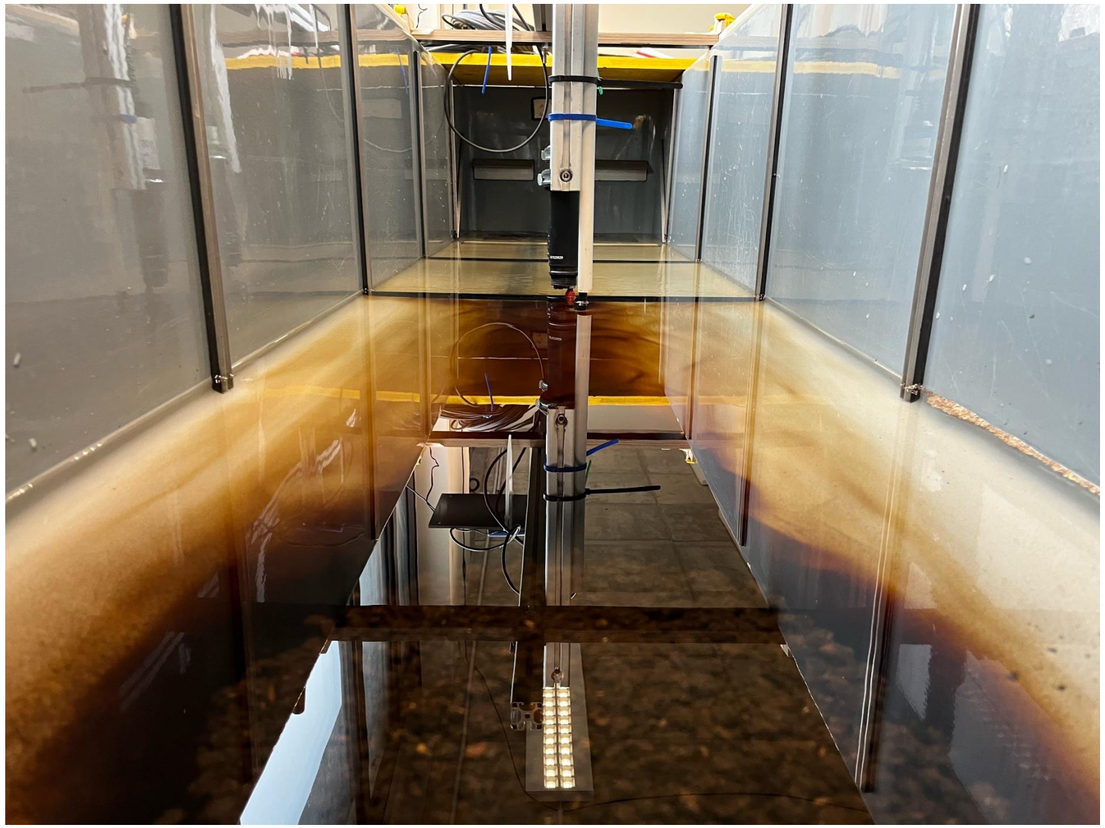

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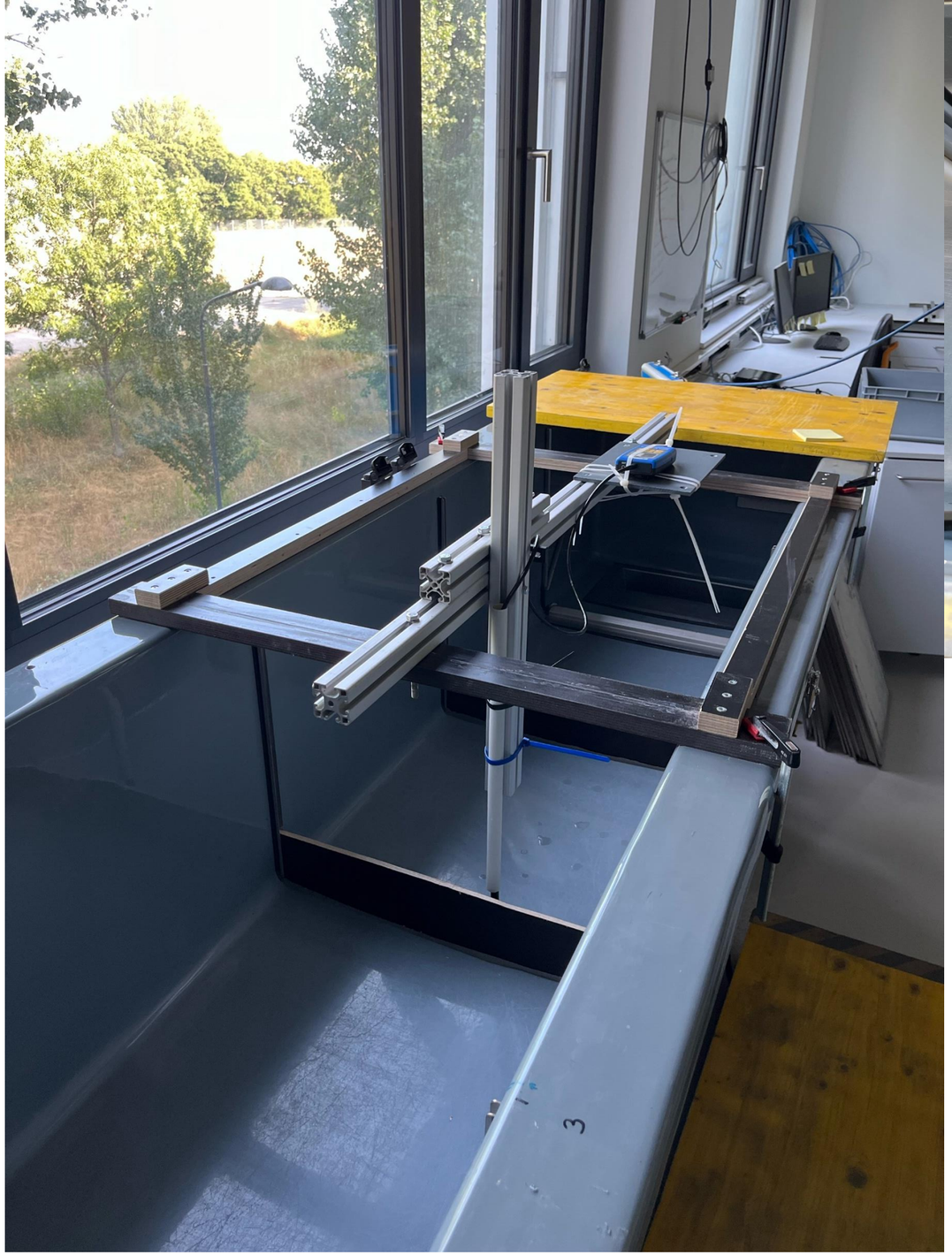

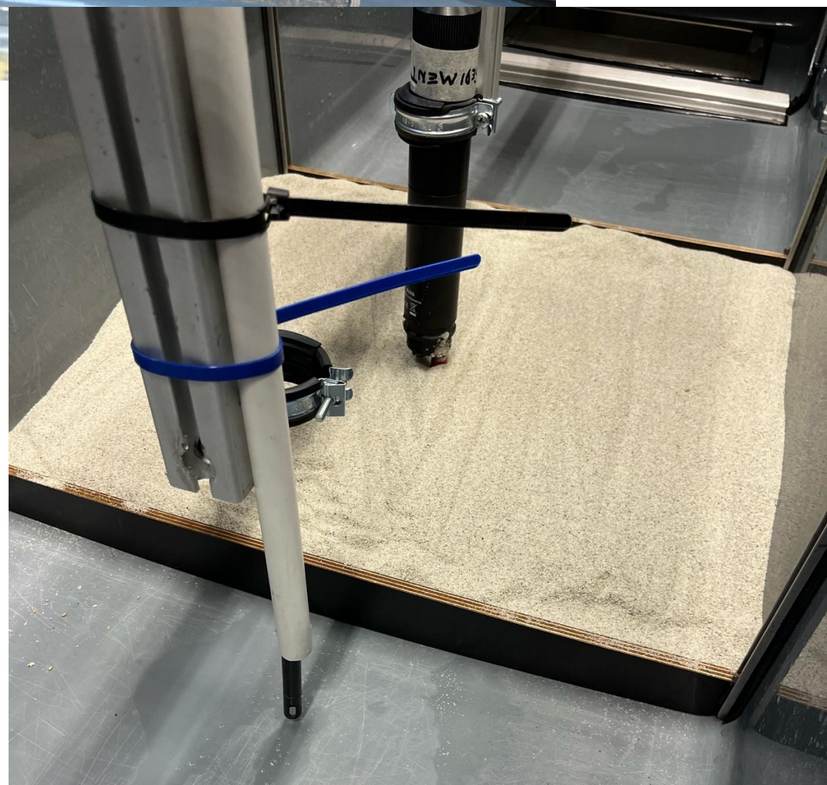

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